5 A steel ball on the end of a thin string oscillates with small oscillations, as shown in Fig. 5.1.

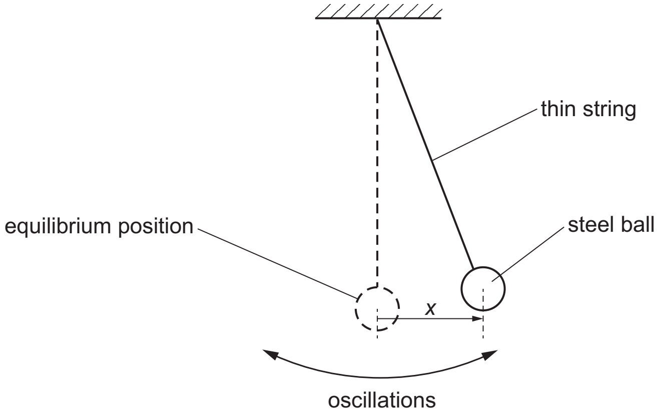

Fig. 5.1 (not to scale)

The displacement of the centre of the ball from its equilibrium position is x.

(a) Fig. 5.2 shows the variation with x of the acceleration a of the ball.

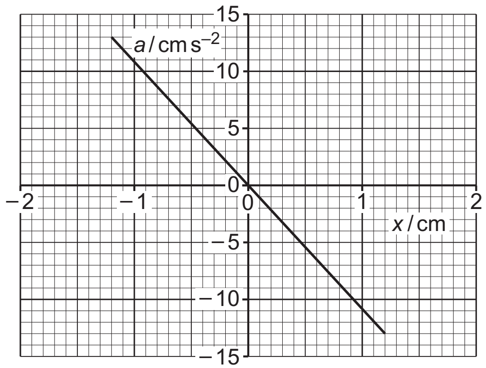

Fig. 5.2

(i) Explain how Fig. 5.2 shows that the oscillations of the ball are simple harmonic.

....

....

.... [2]

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(ii) Determine the period T of the oscillations.

T = ... s [3]

(b) At time $t = 0$, when the displacement of the ball has its maximum value, the ball is immersed in a trough containing thick oil so that the ball is just below the surface of the oil. This results in the subsequent motion of the ball being heavily damped.

(i) State what is meant by damping.

....

....

.... [2]

(ii) On Fig. 5.3, sketch a possible variation of the displacement x of the ball with t between $t = 0$ and $t = 2T$.

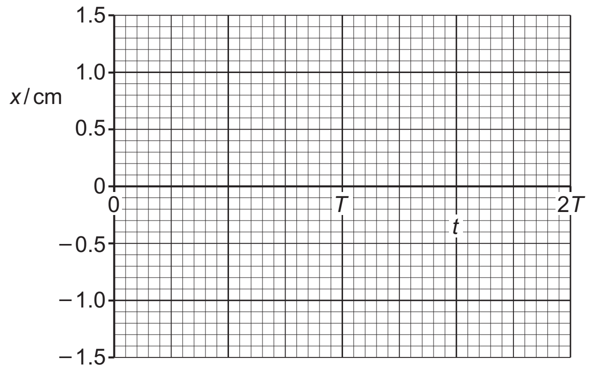

Fig. 5.3

[3]

[Total: 10]

4 (a) State what is meant by the frequency of the oscillations of an oscillating object.

....

.... [1]

(b) An object is oscillating.

Fig. 4.1 shows the variation of the acceleration a of the object with its displacement x from the equilibrium position.

Fig. 4.2 shows the variation of the kinetic energy E_K of the object with time t.

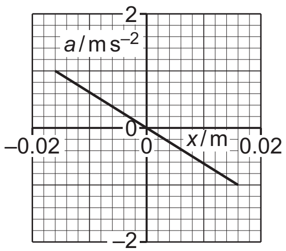

Fig. 4.1

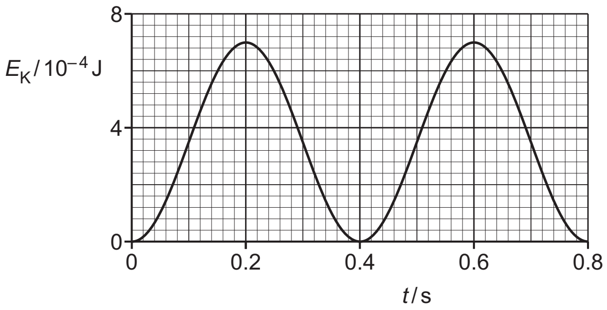

Fig. 4.2

(i) Explain how Fig. 4.2 shows that the period of the oscillations is 0.80 s.

....

....

.... [1]

(ii) Calculate the angular frequency ω of the oscillations.

ω = ... rad s^{-1} [2]

(iii) Apart from the period, frequency and angular frequency of the oscillations, determine **three** other conclusions about the object and its oscillations that may be drawn from Fig. 4.1 and Fig. 4.2. The conclusions may be qualitative or quantitative. Use the space below for any working.

1 ....

....

2 ....

....

3 ....

....
[3]

(iv) Describe the interchange between kinetic energy and potential energy during the oscillations. Numerical values are **not** required.

....

....

....

....

.... [3]

[Total: 10]

5 **(a)** State what is meant by simple harmonic motion.

....

....

.... [2]

(b) A block is suspended by a spring. The block oscillates vertically with simple harmonic motion.

The velocity v of the block varies with time t according to

$$v = 0.56 \cos 16t$$

where v is in $m\,s^{-1}$ and t is in s.

(i) Calculate the period of the oscillation.

period = ... s [1]

(ii) Determine the amplitude x_0 of the oscillation.

x_0 = ... m [2]

(iii) Use your answer in **(b)(ii)** to determine the equation for v in terms of the displacement x of the block, where v is in $m\,s^{-1}$ and x is in m.

v = ... [1]

(iv) On Fig. 5.1, sketch the variation of v with x.

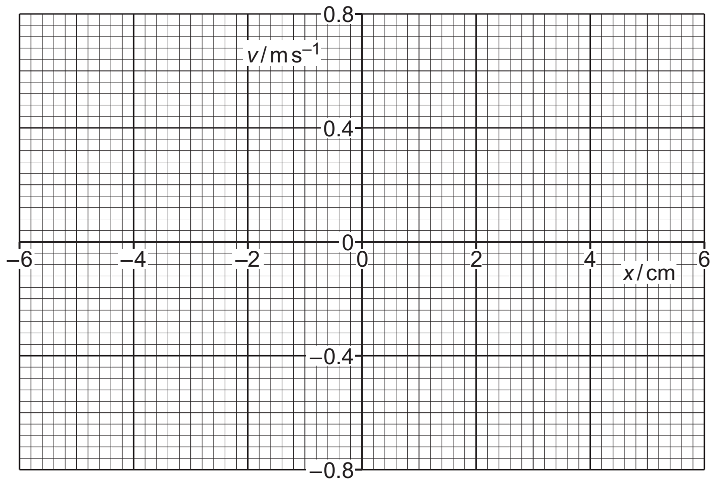

Fig. 5.1

[3]

[Total: 9]

5 A cuboidal block floats in a liquid with its base horizontal, as shown in Fig. 5.1.

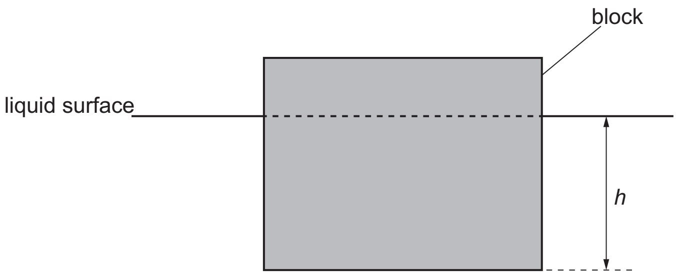

Fig. 5.1

The base of the block is at a depth *h* below the surface of the liquid.

The block is displaced downwards by a small distance and then released so that it oscillates.

Fig. 5.2 shows the variation with *h* of the acceleration *a* of the block.

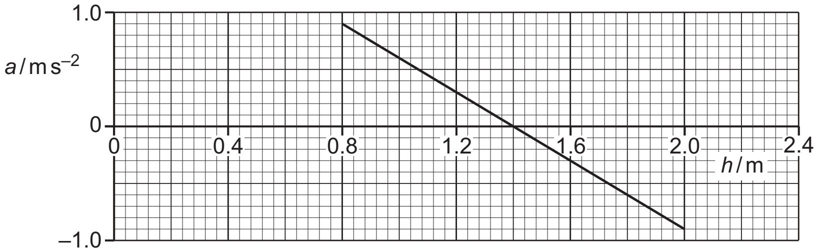

Fig. 5.2

Fig. 5.3 shows the variation with *h* of the kinetic energy E_K of the block.

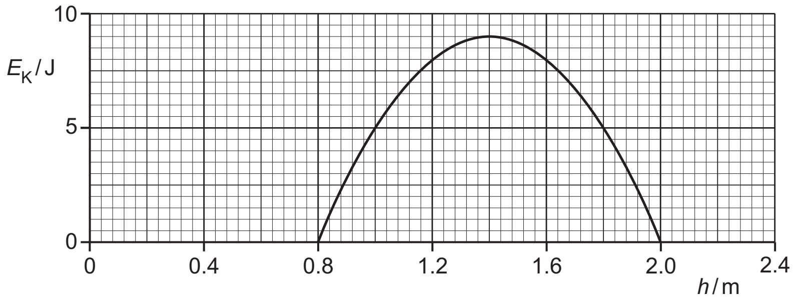

Fig. 5.3

(a) **(i)** Determine the amplitude of the oscillations.

amplitude = ... m [1]

(ii) State what the line in Fig. 5.2 shows about the nature of the oscillations.

.... [1]

(b) State **three** other quantitative conclusions that can be drawn from Fig. 5.2 and Fig. 5.3 about the block and its oscillations. Use the space for any working.

1 ....

....

2 ....

....

3 ....

....

[3]

(c) On Fig. 5.4, sketch the variation with *h* of the potential energy E_P of the oscillations.

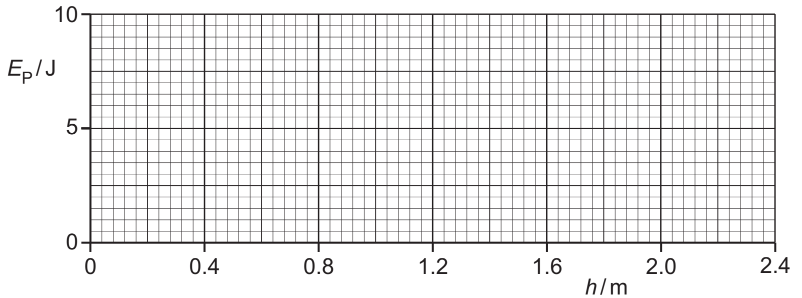

Fig. 5.4

[3]

[Total: 8]

4 **(a)** State what is meant by simple harmonic motion.

....

....

.... [2]

(b) A small sphere is suspended from a fixed point P by a string of negligible mass, as shown in Fig. 4.1.

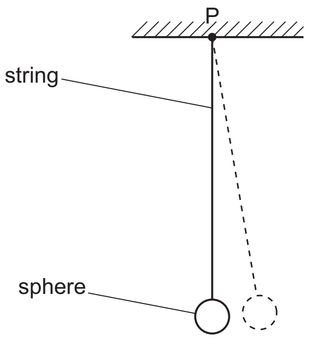

Fig. 4.1

The sphere is given a small horizontal displacement and is then released.

The variation with time of the horizontal velocity *v* of the sphere is shown in Fig. 4.2.

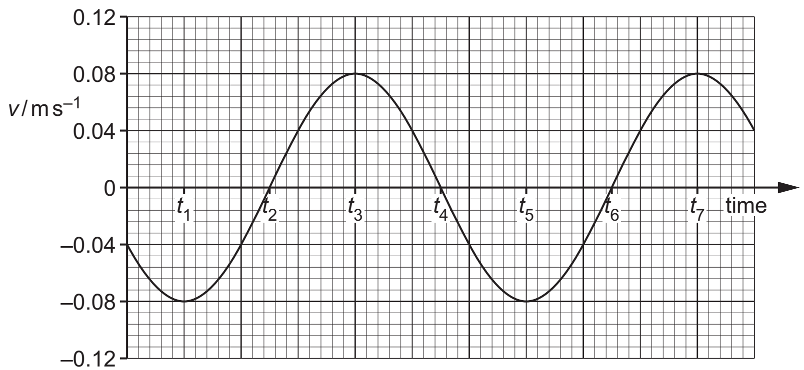

Fig. 4.2

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(i) State two times at which the sphere is passing in the same direction through the equilibrium position.

time .... and time .... [1]

(ii) The time interval between t_1 and t_6 is 2.2 s.

Calculate the frequency of oscillation of the sphere.

frequency = ... Hz [2]

(c) The sphere in **(b)** is undergoing simple harmonic motion.

Use your answer in **(b)(ii)** and data from Fig. 4.2 to determine the maximum displacement of the sphere from its equilibrium position.

maximum displacement = ... m [3]

[Total: 8]

4 A small crystal is made to vibrate with simple harmonic motion. The variation with time t of the displacement x of one surface of the crystal from its equilibrium position is shown in Fig. 4.1.

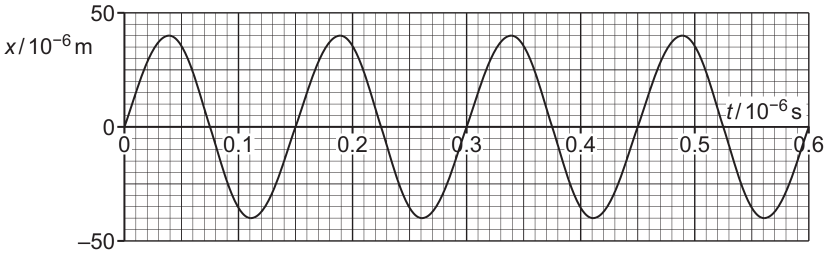

Fig. 4.1

(a) Show that the angular frequency of the vibration of the surface is 4.2×10^{7} rad s^{-1}.

[2]

(b) Determine the maximum acceleration a_0 of the vibration of the surface.

a_0 = ... m s^{-2} [2]

(c) The crystal may be modelled as a single mass of 2.4×10^{-4} kg that vibrates as shown in Fig. 4.1.

Calculate the total energy E of the vibrations.

E = ... J [3]

(d) The crystal generates ultrasound waves that are used to obtain diagnostic information about internal structures.

(i) The crystal is made from piezoelectric material.

Explain how the crystal is made to vibrate.

....

....

....

.... [2]

(ii) A parallel beam of ultrasound waves is incident on a muscle-bone boundary. Data for muscle and bone are given in Table 4.1.

Table 4.1

material	density / kg m^{-3}	speed of sound / m s^{-1}
muscle	1100	1600
bone	1900	4100

Calculate the percentage of the intensity of the ultrasound beam that is transmitted at this boundary.

percentage transmitted = ... % [3]

[Total: 12]